ARPA-E Background &

Workshop Rationale

Wednesday, October 21, 2009

ARPA-E: The Story to Date

ARPA-E: Planning for the Future

Novel Approaches to Direct-Solar Fuels

America COMPETES Act 2007 and the Establishment of ARPA-E

Mission

- To "enhance the economic and energy security of the US" through:
  - "Reduction in energy imports"
  - "Improvement in energy efficiency"
  - "Reduction in energy-related emissions, including greenhouse gasses"
- To "ensure" US "technological lead in developing and deploying advanced energy technologies"

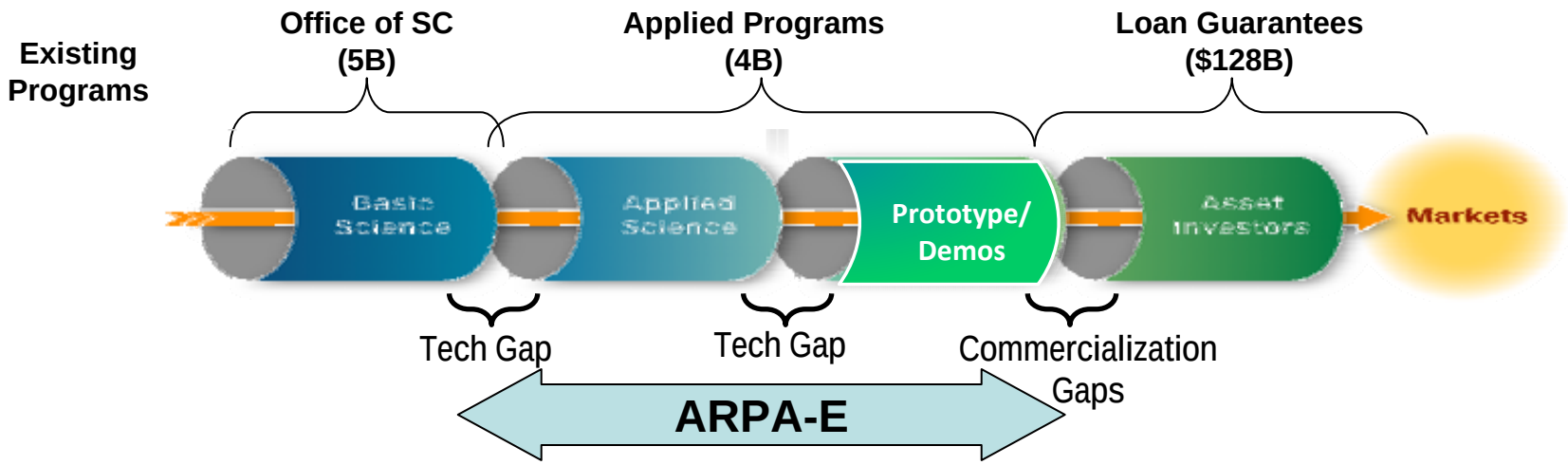
Means

- "Identifying and promoting" [but not itself making] "revolutionary advances in fundamental sciences"
- "Translating scientific discoveries and cutting edge inventions into technological innovations"
- "Accelerating transformational technological advances in areas that industry by itself is not likely to undertake…"
- Authority for: testing and evaluation, demonstration, mfg. technology, tech transfer

Key Takeaways

- Creates a new organization within DOE, reporting directly to the Secretary (PAS)
- Hiring and management unrestricted by civil service laws
- Lean, flat organization (70-120 program managers) with rapid, continual turn-over
- Can engage universities, industry, and when in consortia with others, FFRDC labs

ARPA-E bridges the gaps in the energy innovation pipeline



What ARPA-E will do

- Disruptive transformational projects
- High risk, high potential programs
- Projects in need of rapid and flexible experimentation/engineering
- Marry technical opportunities with mission gaps
- Breakthrough science that can transform a field
- Outcome focused: to meet climate & energy security objectives; not on a particular scientific problem
- Technology development

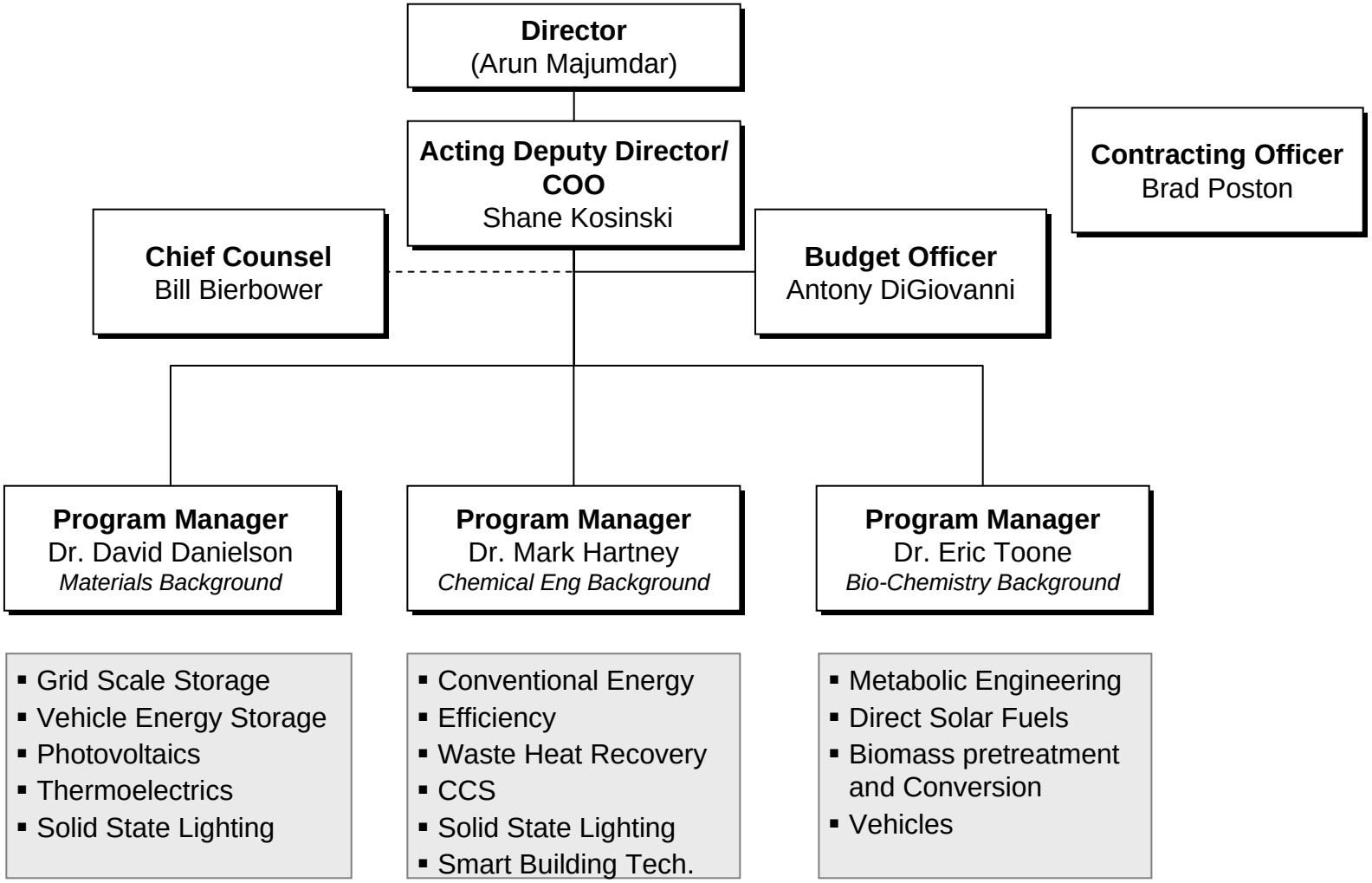
What ARPA-E will not do

- Basic Research
- Lowest Technology Readiness Levels project
- Projects longer than 5 years
- Evolutionary improvements
- Large scale commercial viability demos

Currently ARPA-E is in startup mode with only 6 dedicated employees supported by consultants in a variety of tasks

ARPA-E Organization Chart

Current



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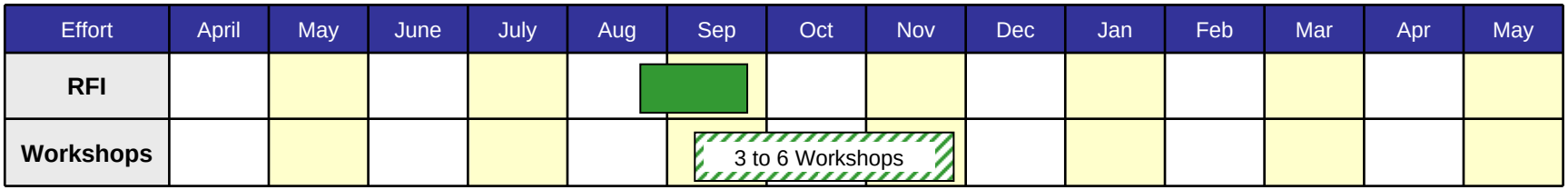
In addition to FOA #1, outreach efforts including the RFI and workshops must occur for FOA #2



RFI

- Formal process to survey relevant public input on programmatic areas; on specific scientific opportunities and on technological roadblocks to the development of market deployable technology
- RFI published on August 31
- Intended Outcome include
  - Clear articulation of game changing technologies & challenges
  - Justification for investment in areas
  - Listing of potential interest areas for next FOAs
  - Input in other transformational areas

Workshops

- Focused workshops on potential program areas
  - Grid Scale Energy Storage
  - Energy Storage for Vehicles
  - Direct Solar Fuels
  - Carbon Capture & Sequestration
- Need state of the art knowledge, assemble data to issue future grand challenges, opportunities for ARPA-E
- Lining up key participants – external speakers/thought leaders to validate areas
- Request participation from Basic Sciences and Applied Programs to provide overview of their programs and help identify potential opportunities and overlaps

To complement the RFI, ARPA-E workshops will convene experts and visionaries to gather input for future FOAs

Workshops	Workshops Details
Grid Scale Energy Storage **Oct 4**	▪ Goal is to better understand technological challenges and emerging opportunities in Grid Scale Energy Storage to enable the large scale integration of intermittent renewable into the grid ▪ Co-located with the Electrical Energy Storage Applications and Technology Conference, ▪ Co-chaired with the DOE Office of Electricity
Direct-solar Fuels **Oct 21**	▪ Goal is to better understand the technical challenges surrounding direct-solar fuel technologies, and identify R&D paths to overcome these challenges ▪ Focus on biological approaches to re/engineer photosynthesis, biomimetic / inorganic approaches to artificial photosynthesis, and photolytic/ photoelectrochemical conversion of carbon dioxide to liquid fuels
Carbon Capture & Conversion Week of Oct 29	▪ Goal is to identify out-of-the-box approaches to the capture and re-use of carbon dioxide ▪ In discussion with NETL Carbon Capture & Sequestration staff to co-chair ▪ Potential areas of focus: membranes, metal organic frameworks, ionic liquids, materials tolerant to flue gas pollutants, advanced catalysis, solar/electro reduction of carbon dioxide
Automotive Storage **Nov 3**	▪ Goal is to best inform the technological needs in automotive batteries for PHEV and EVs, ultra/super capacitors, and novel charge-discharge technologies ▪ Co-Chaired with the DOE Office of Vehicle Technologies ▪ Focus on advanced electrochemical storage technologies as well as manufacturing techniques

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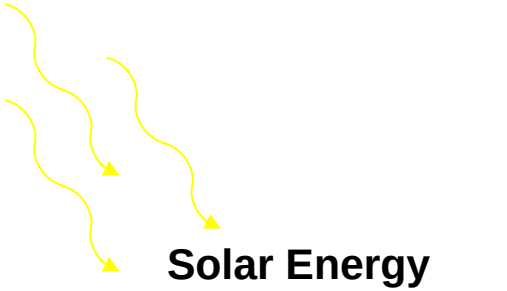
Novel Approaches to Direct-Solar Fuels

Solar energy is an energy panacea but economics of conversion, storage, and deployment are challenging



Solar Energy Capture/Conversion

Electricity → Residential, Industrial & Transportation

Widespread deployment is dependent on significant infrastructure additions and modifications, including large-scale electricity storage, electric vehicles, etc.

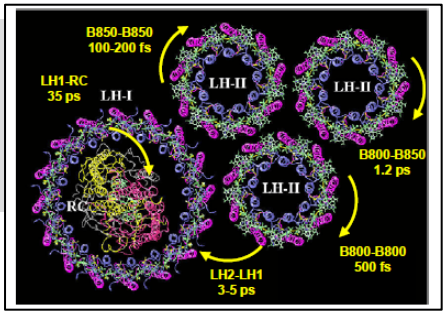
Hydrocarbon Fuels → Residential, Industrial & Transportation

The conversion of solar energy to hydrocarbon fuels derived from either biomass or **directly from carbon dioxide and sunlight** circumvent critical infrastructure integration issues.

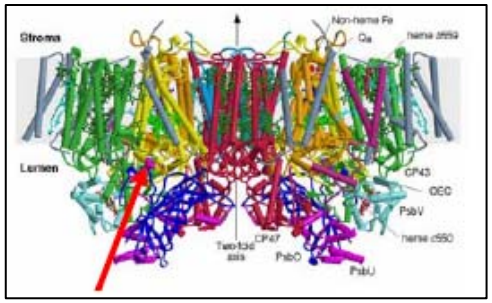
Biomass production and conversion to fuels, including hydrocarbons, is an interesting and promising area of research investment which is supported by various DOE, USDA, EPA, and DOT programs. ARPA-E is currently interested in exploring the potential for direct-solar approaches which can add to existing biomass conversion efforts.

Significant basic science research observations and advancements have been made in support of direct-solar fuels

Photosynthesis to guide development of artificial photosynthetic systems

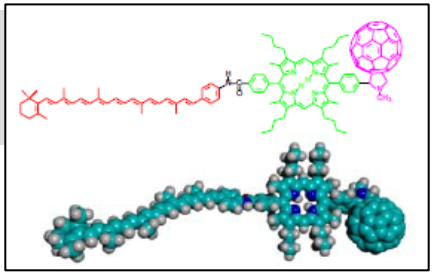


Bacterial Antenna Proteins



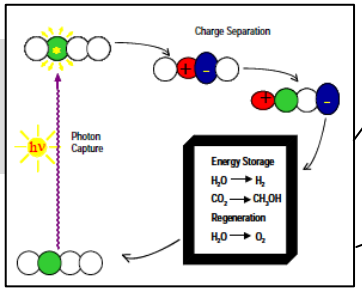
Plant Photosystem II

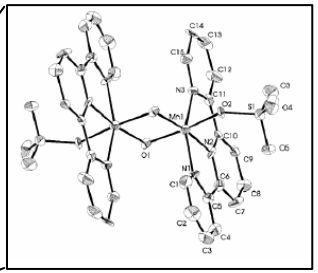
Photo-initiated charge separation and storage



Carotene-Porphyrin-Fullerene

Photocatalysis to drive reactions

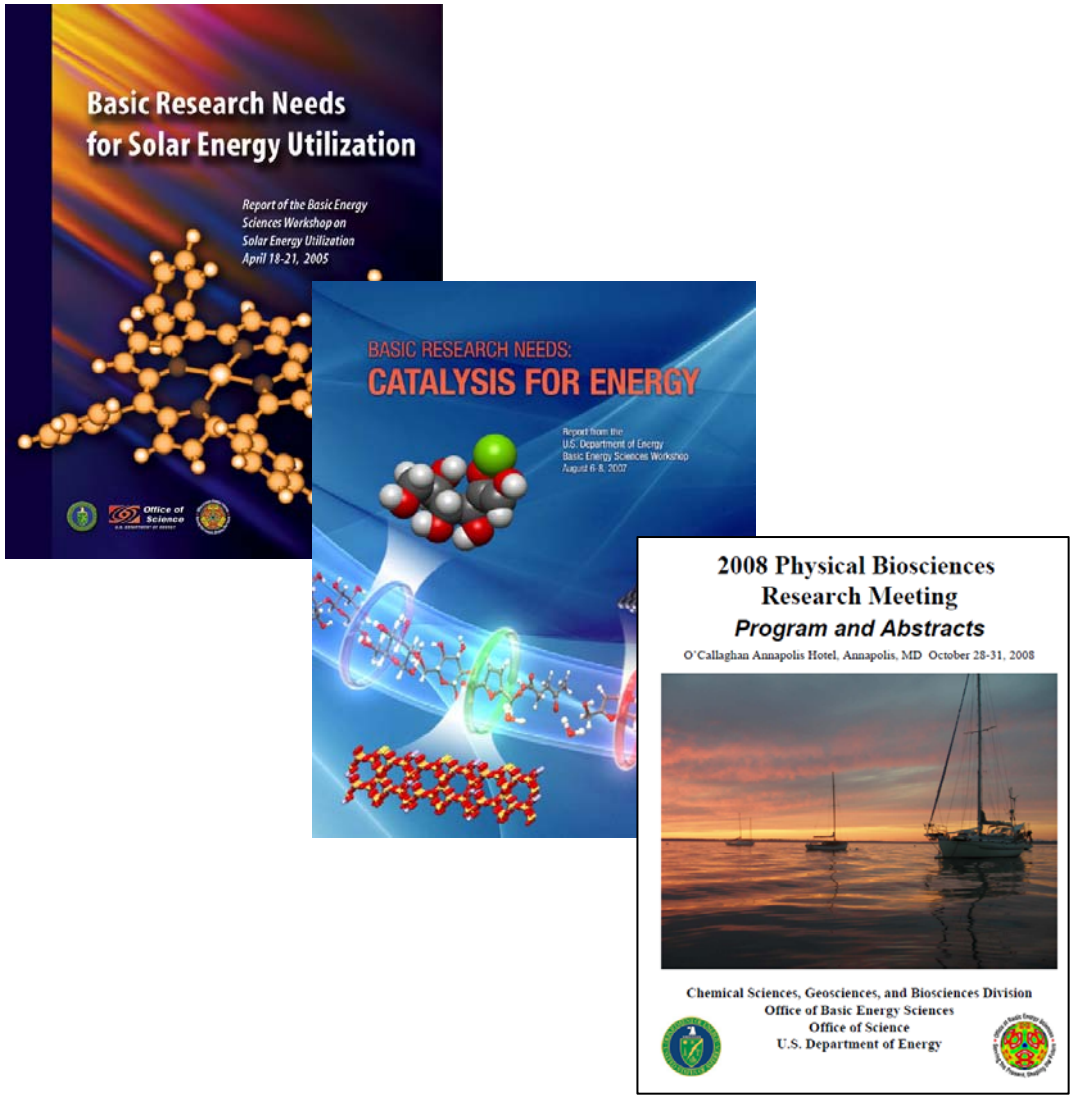




Catalysts can be used to reduce CO_2 and split H_2O

All figures taken from Basic Research Needs for Solar Energy Utilization-Report of the Basic Energy Sciences Workshop on Solar Energy Utilization, DOE, April 18-21, 2005

DOE Office of Basic Energy Sciences has a long history of support for basic research in direct solar fuels

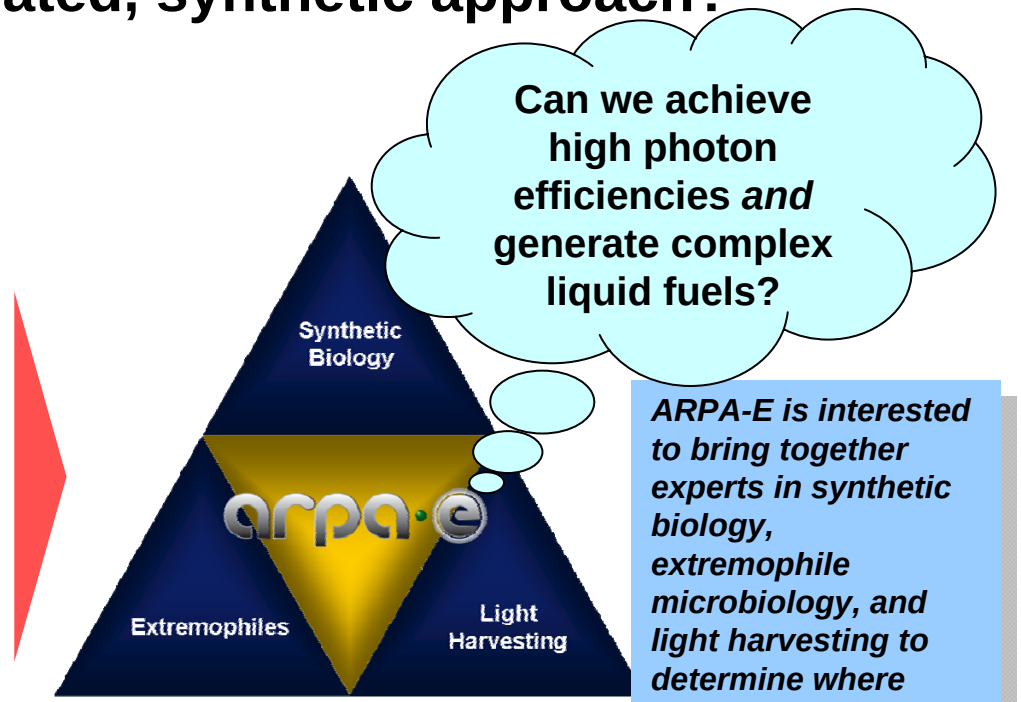


- ARPA-E will build on and leverage efforts of BES and other agencies;
- ARPA-E will not fund basic scientific research;
- Rather, ARPA-E may explore the potential of combining and transitioning wide-ranging and disparate discoveries and capabilities to create a deployable technology.

The challenge: can limitations of current approaches be overcome with a more integrated, synthetic approach?

Artificial light harvesting has been demonstrated **but photocatalysis beyond methane is a challenge**

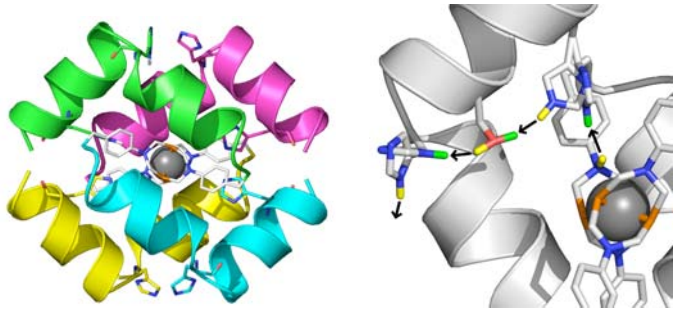
Single photosynthetic organisms suffer from **low photon efficiency**



ARPA-E is interested to bring together experts in synthetic biology, extremophile microbiology, and light harvesting to determine where these pursuits intersect and can work synergistically.

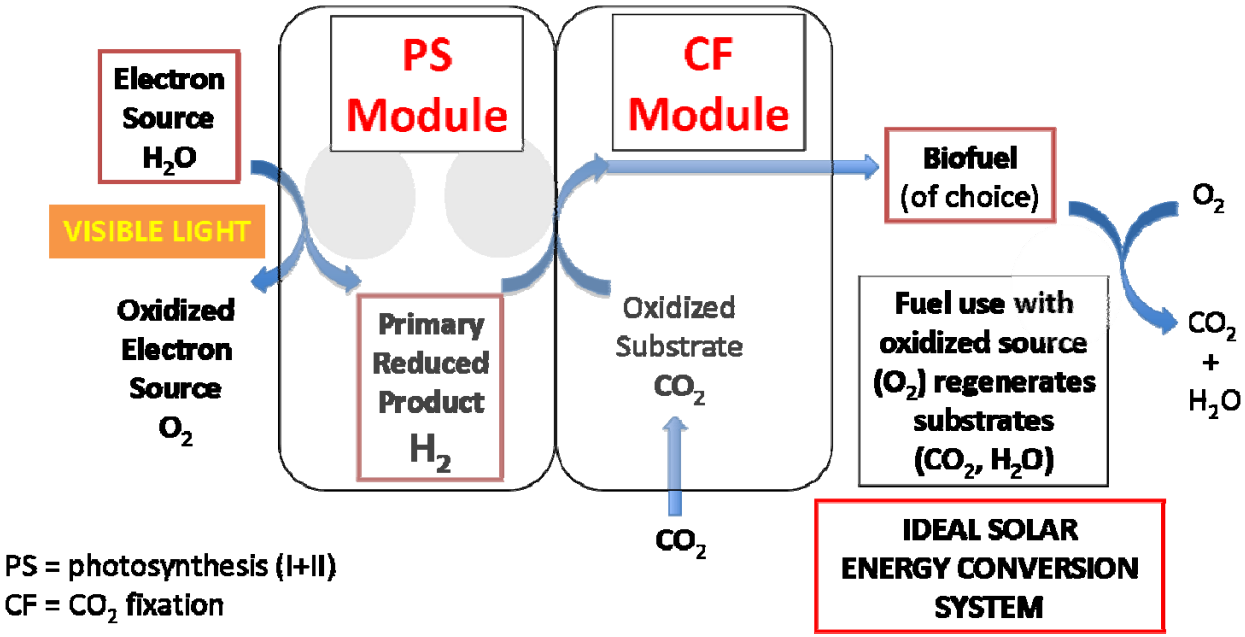
What other technologies are available for this effort?
Unnatural proteins (Evolution? Design?)

What other technical disciplines can add value to this effort?



David Baker, University of Washington
David Dubois, PNNL

How can photon capture and electron transduction systems be coupled to CO_2 fixation to build long chain hydrocarbons?



Engineered systems could involve one or more organisms, or be a biological/abiological hybrid system. Or….

Mike Adams, University of Georgia

Examples of Key Challenges:

- **Mechanisms of energy transduction between photon capture, biosynthesis modules;**
- **Mechanisms of spontaneous assembly;**
- **Means of assembling biotic, abiotic components.**

……what else are we missing, what else can we accomplish?